Evaluation of groundwater droughts in Austria

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Introduction and Methods

This work analyzes time series of groundwater levels from various, mostly unconsolidated, aquifers in Austria to characterize the effects of droughts on aquifers in different hydrogeologic and climatic settings as well as under different usage scenarios. 1400 groundwater time series from Austria, all ranging back longer than 1971, have been analyzed.

Besides visual inspection of the waterlevels, the data also was standardized to allow for comparisons of different locations. Two methods were used:
1. The $x = (x_i - \mu)/\sigma$ approach, and 2. calculating their Standardized Groundwater Index - SGI, according to Bloomfield and Marchant (2013), which in turn is based on the Standardized Precipitation Index - SPI by McKee et al (1993). A SGI value of 3 is defined as very wet, whereas -3 is defined as severe drought.

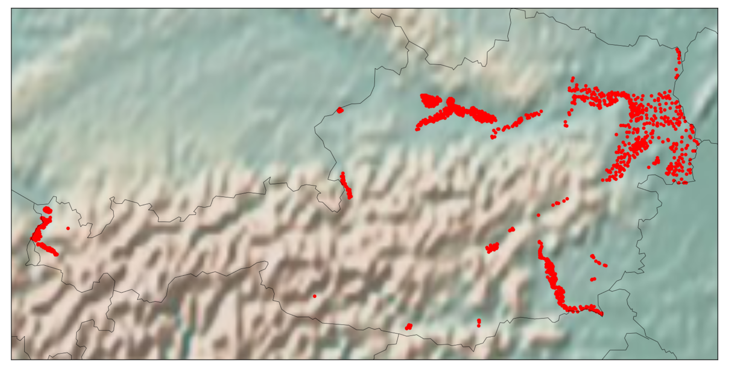


Figure 1: Locations of the wells, mostly following the Austrian lowlands and large valleys, concordant with the distribution of the Austrian population.

Preliminary Results

The standardization of the data allows to calculate a mean SGI over the whole of Austria (see figure 2). A decreasing trend until the beginning of the 1980's can be seen. However this trend also correlates with the continuing increase of the number of measurement wells (see figure 3), so there is a probability that this decrease is caused by wells from comparably dry regions being added to the dataset.

Depending on weather conditions and river stages, various patterns of wet and dry conditions in groundwater can develop, both in time, as well as geographically (see figure 4).

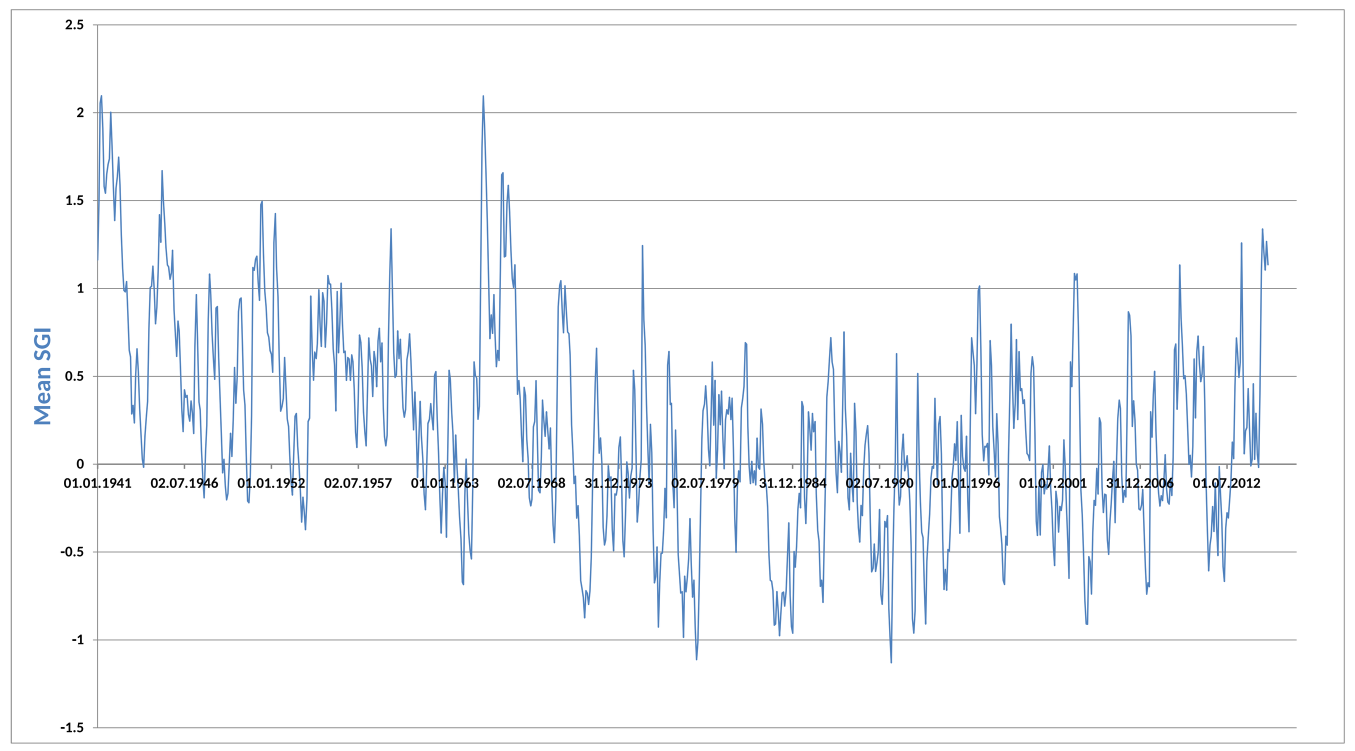


Figure 2: Mean SGI for the dataset, showing a decreasing mean SGI until the early 1980's and an increase afterwards.

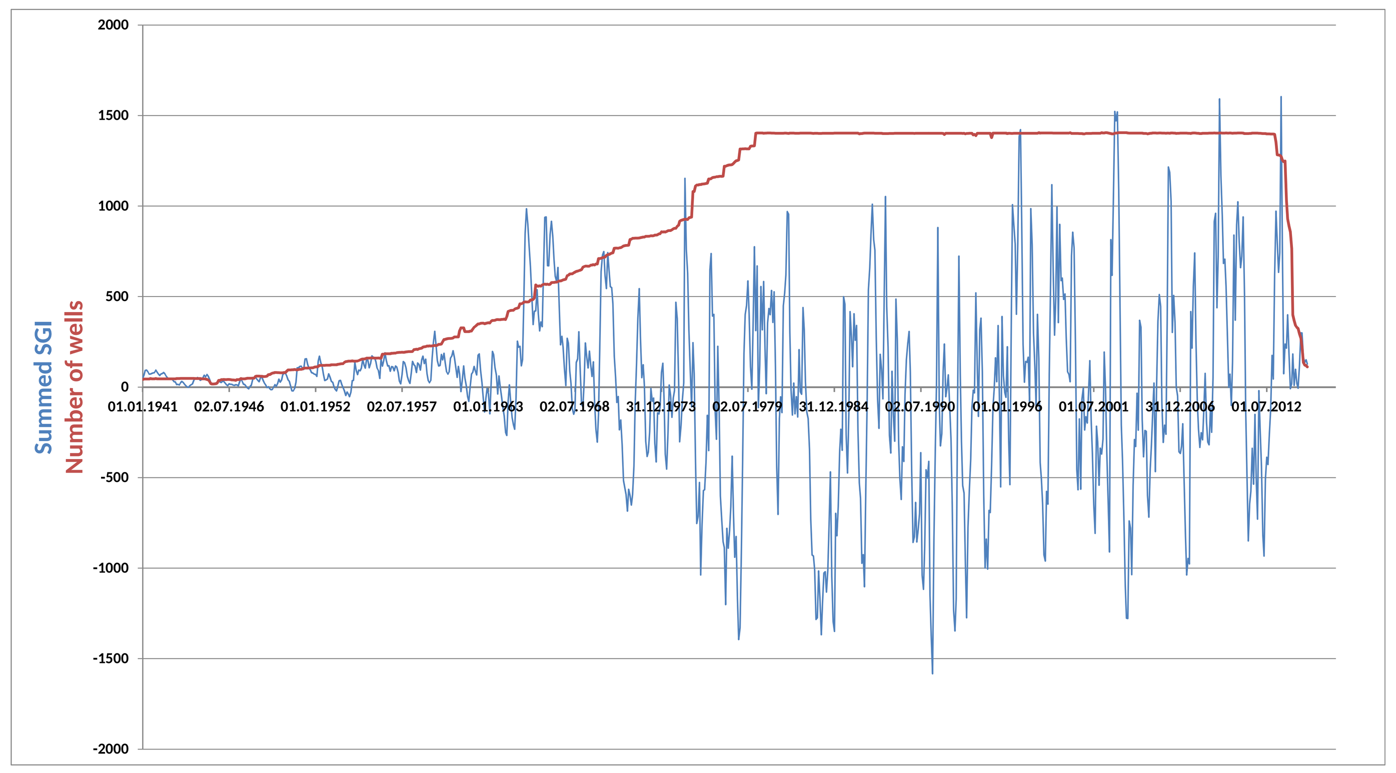
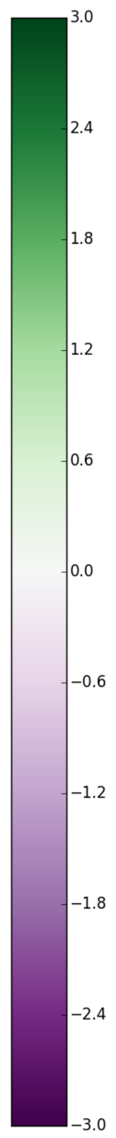
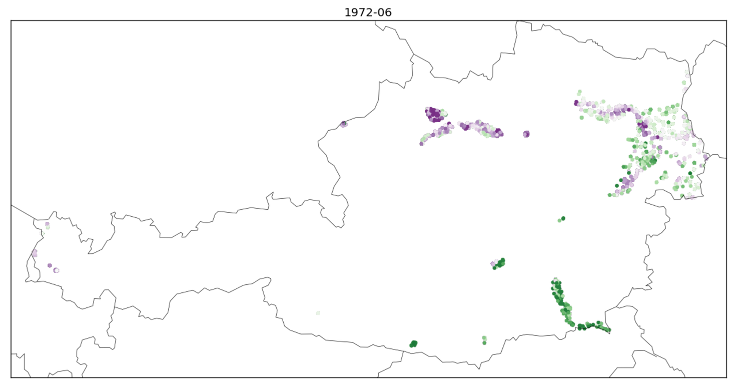
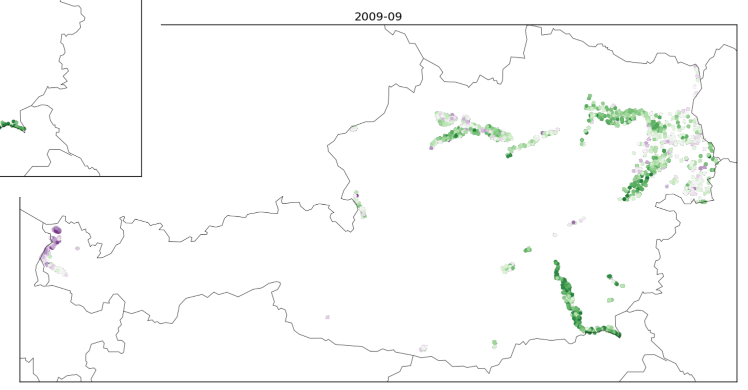
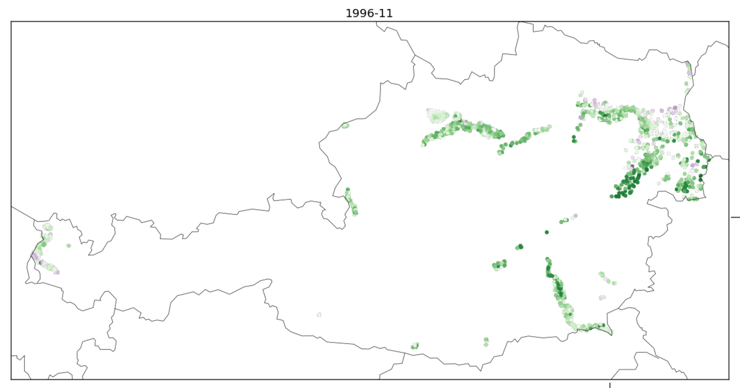


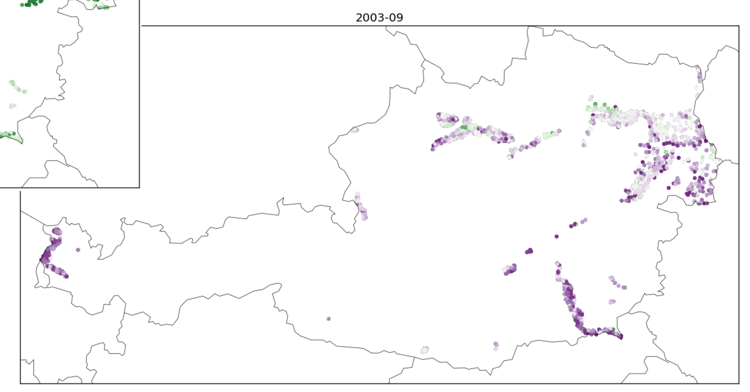
Figure 3: Summed SGI for the dataset and increasing number of wells over time, matching the decrease of SGI shown in Figure 2.

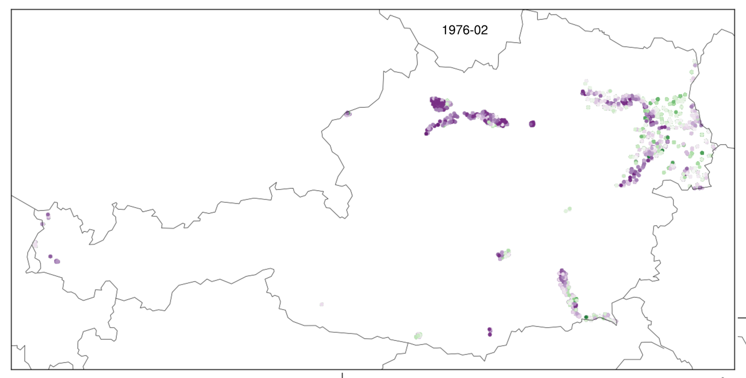


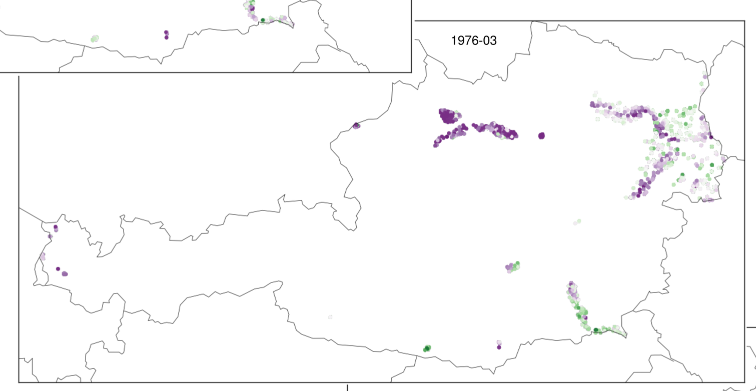
Geographical patterns, showing differences between North and South (top) and East and West (right).

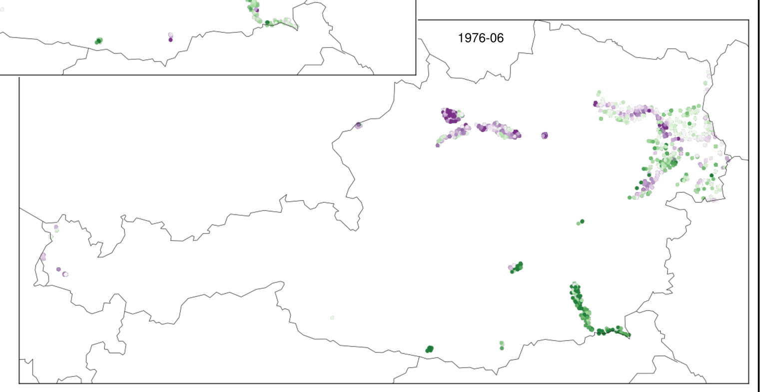




Example for a wet winter (top) and a dry summer (right).







Recovery from a dry winter in the South, dry conditions staying in the North

Figure 4: Examples for various wet and dry patterns

Discussion and further work

The current dataset only concentrates on the most populous areas of Austria, missing out the Alpine Regions and the Bohemian Massif in upper Austria. An inclusion of alpine wells, possibly directly influenced by glacial melt, should yield further, interesting results.

The dataset shows many time series where a rapid change occurs (see e.g. figure 5). For those it is important to automatically identify such occurrences, to be able to investigate their causes, which are likely to be anthropogenic.

Such phenomena, as well as waterlevels that show a general trend (see figure 5) pose the question whether groundwater levels can be seen as stationary.

As can be seen in figures 6, a dataset with a large jump will yield different and more consistent SGI's when split up to omit the jump, whereas the original dataset yields a wet and a dry period.

Given the fact that jumps occur in 2.6 % of the dataset, such "artificial" wet and dry periods do not interfere with the countrywide mean SGI (see figure 2).

It is also of note, how wet or dry conditions propagate through the aquifers, and how they are distributed countrywide.

Distinct subregions with local SGI trends (see figures 4 and 5) can show a different behavior from the countrywide mean SGI.

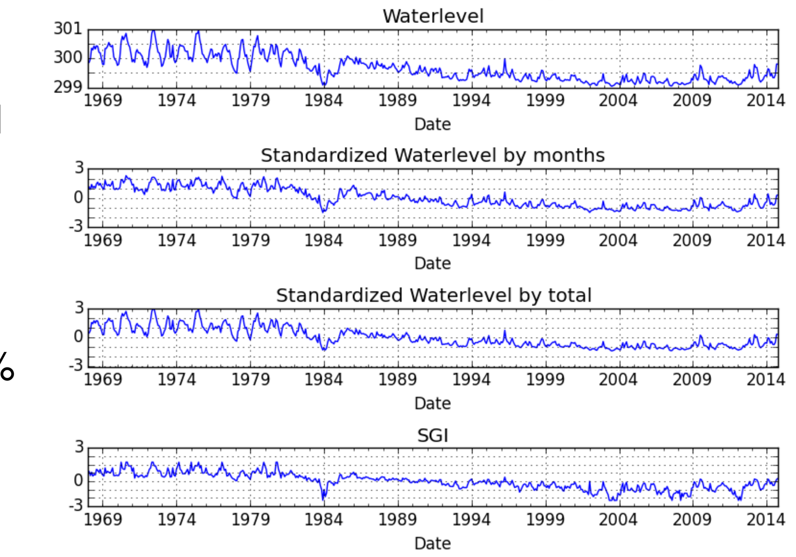
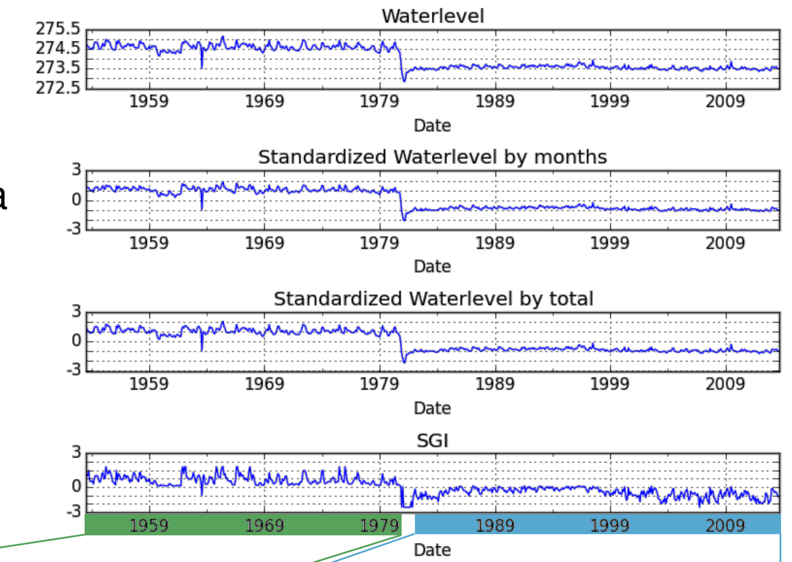


Figure 5: Example of a well with trend in waterlevel change, located in the Mur catchment, southern Austria



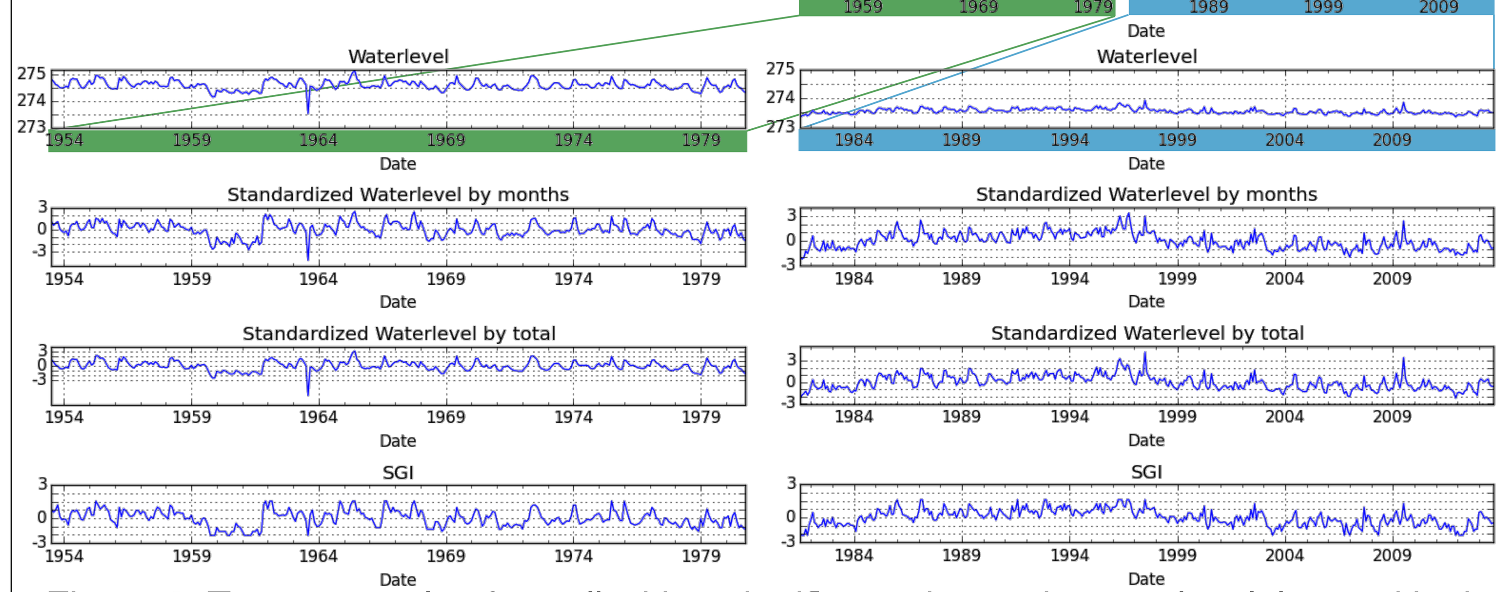


Figure 6: Top - example of a well with a significant change in waterlevel, located in the Vienna region. Bottom - split dataset for this location.

Acknowledgment:
This work was funded by the Austrian Science Fund (FWF) under research grant W 1256-G15 (Doctoral Programme Climate Change - Uncertainties, Thresholds and Coping Strategies)

References:
Bloomfield, J.P. & Marchant, B.P. "Analysis of groundwater drought building on the standardised precipitation index approach" Hydrology and Earth System Sciences, 2013, 17, 4769-4787
McKee, T.B., Doesken. N.J. and Kleist, J. "The relationship of drought frequency and duration to time scales." Proceedings of the 8th Conference on Applied Climatology. Vol. 17. No. 22. Boston, MA: American Meteorological Society, 1993